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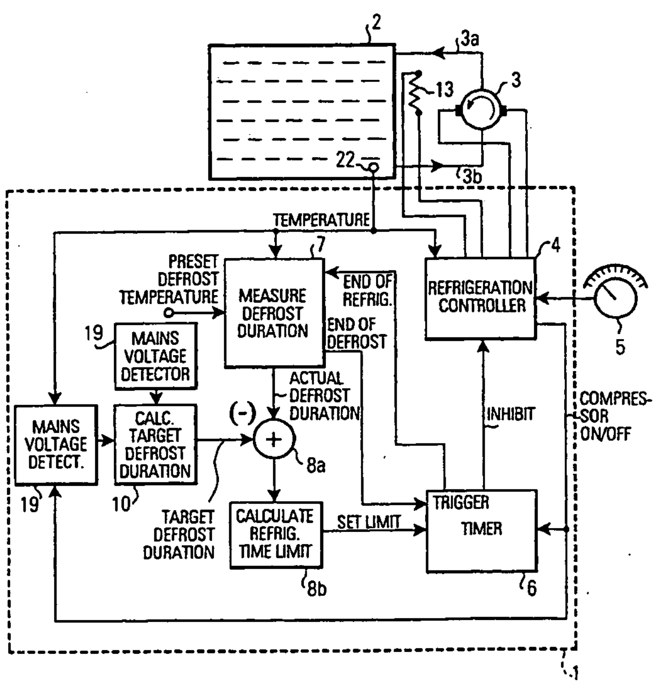
(54) Controller and method for controlling a defrost operation in a refrigerator

(57) The present invention relates to a controller (1) and a method of controlling a defrost operation in a refrigerator. The duration of a refrigeration period is determined by the amount of time needed for defrosting the evaporator (2) of the refrigerator. A heater (13) is provided for supplying thermal energy to accelerate the defrost operation. If the defrost duration deviates from a target defrost duration, the next refrigeration period is adjusted accordingly to maintain the actual defrost duration close to the target defrost duration. According to the invention the target defrost duration is determined based on the detection of a power supply condition of the refrigerator. Preferably, also the thermal dispersion is detected. The invention achieves an optimized adaptive defrost even when operating the refrigerator in countries where the mains power supply suffers from load dependent voltage instabilities.

FIG.3



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Description

[0001] The present invention relates to a controller and a method for controlling a defrost operation in a refrigerator, according to the preamble of claims 1 and 21. A controller and a method of this kind are known from DE 29 45 691.

[0002] From this document a controller for defrosting the evaporator of a refrigerator is known which adaptively controls a defrost operation for melting ice accumulated on the evaporator during a refrigeration period, that is during a period of normal operation of the refrigerator to maintain a food compartment of the refrigerator at a desired temperature. From this document it is known that when the compressor of the refrigerator is switched off to start a defrost operation, the time taken for the evaporator to reach a preset temperature above 0°C is approximately proportional to the amount of ice accumulated on the evaporator during the preceding refrigeration period. Heater means are provided for supplying heat to the evaporator during the defrost operation.

[0003] To reduce the frequency of defrost operations and therefore save energy, the known controller delays a next defrost operation by a factor dependent on the time the evaporator takes to reach the preset temperature during the defrost operation. The known controller measures the duration of a defrost time interval until the evaporator has reached the preset defrost temperature. If this duration is less than a predetermined target defrost duration, the known controller extends the next refrigeration period. If the defrost duration is larger than the target defrost duration, the known controller reduces the next refrigeration period and hence advances the beginning of the next defrost period. In this way, the known controller saves energy by carrying out less defrost operations in conditions of low ice formation rate. Similarly, if the ice formation rate is high, the frequency of defrost operations is increased thus ensuring that the evaporator stays largely ice free and hence operates at high efficiency.

[0004] The time taken by the evaporator to reach the preset defrost temperature above 0°C, signaling the end of a defrost operation, is influenced not only by the amount of ice on the evaporator when an additional source of thermal energy, e.g. an electric heater, is used for accelerating the defrost operation. The duration of the defrost time interval until the evaporator has reached the preset defrost temperature also depends on the amount of heat supplied by the additional source of energy per time unit to the evaporator during the defrost operation. The energy that is supplied per time unit by the additional source of thermal energy in turn depends on the present condition of the power supply that feeds the thermal energy source. For example, if the mains voltage feeding the refrigerator varies over time and an electric heater means is used to accelerate the defrost operation, the mains voltage variations will have an impact on the duration of the defrost time interval. An estimate of the amount of ice accumulated at the evaporator based on the defrost time interval alone can therefore be quite inaccurate. Fig. 1a shows a typical behavior of the evaporator temperature T over time in a first condition A when the power supply of the refrigerator is weak, e.g. the mains voltage is low, and in a second condition B when the power supply is strong, e.g. the mains voltage is high. From Fig. 1a it can be taken that when the power supply is weak, the thermal power provided by the heater to accelerate the defrost operation is low such that a defrost time interval t_1 is comparatively large. If the power supply is strong, the thermal power is high, resulting in a reduced defrost time interval t_2 until the evaporator has reached the same defrost temperature as in condition A. In a power supply condition A, the known controller will detect a defrost time interval T_1 larger than the target defrost duration and will accordingly increase the frequency of defrost operations. In a power supply condition B shown in Fig. 1a, for the same amount of ice as in case of condition A the controller detects a shorter defrost time interval t_2 than the target defrost duration and therefore decreases the frequency of defrost operations, that is increases the refrigeration period between consecutive defrost operations. This shows that the behavior of the known controller is less than optimum, because in condition A the controller will keep the refrigeration period shorter than necessary and thus waste energy, while in condition B the amount of ice accumulating on the evaporator will grow. This again results in a waste of energy due to a reduced efficiency of the evaporator.

[0005] The known controller is furthermore unable to take into account the thermal dispersion through the refrigerator appliance insulation. Also, it initiates a defrost immediately after the calculated refrigeration period time limit has expired. This has the disadvantage that the duration of the defrost time interval until the evaporator has reached the preset defrost temperature depends on the temperature of the evaporator at the end of the refrigeration period. Fig. 1b shows a first situation A that the refrigeration period ends with the evaporator temperature having a comparatively high value. Fig. 1b furthermore shows a situation B where the refrigeration period ends with the evaporator temperature being at a comparatively low value. The total amount of time required for the evaporator to reach the preset defrost temperature differs in both situations A and B. In situation A, the known controller will set the next refrigeration period time limit different than in situation B, due to the timing error in the defrost time interval. This again results in refrigeration periods less than optimum and in an increased energy consumption of the refrigerator.

[0006] Moreover, the known controller always reacts to past icing conditions on the evaporator. The accumulation of ice on the evaporator generally results from opening the refrigerator door. If after a defrost operation a user frequently opens the refrigerator door in the sub-

sequent refrigeration period, the amount of ice actually accumulating on the evaporator may differ substantially from what was detected during the previous defrost operation.

[0007] The known controller is not able to react appropriately to this situation. It cannot prevent that in the course of the current refrigeration period with many door openings a lot of ice accumulates hence lengthening the time taken for the evaporator to reach the preset defrost temperature. This will cause the known controller to shorten the next refrigeration period even if the rate of ice accumulation returns to normal.

[0008] This results in an increased energy consumption of the refrigerator.

[0009] It is, therefore, an object of the present invention, to provide a controller and a method for controlling a defrost operation in a refrigerator such that the refrigerator can operate energy-efficiently even under varying conditions of the refrigerator appliance power supply.

[0010] According to the present invention, this object is solved as defined in claims 1 and 21. According to the present invention, a power supply condition of the refrigerator is detected and the target defrost duration is adjusted in accordance with the detected thermal dispersion.

[0011] As a matter of convenience the detected power supply condition can be the mains voltage or the current through the electrical heater when in operation. It would however be feasible to detect the present power supply condition for instance by means of measuring the temperature of the electrical heater means or even its temperature dependent electrical resistance when in the energized state.

[0012] By means of adjusting the target defrost duration in accordance with the detected power supply condition of the refrigerator, the present invention allows to adapt the duration of the refrigeration periods to the actual amount of ice accumulated on the evaporator essentially independent from the condition of the mains to which the refrigerator is connected. The present invention therefore improves the energy efficiency of a refrigerator with an adaptive defrost function in an unstable mains voltage environment.

[0013] The optimum target defrost time can be determined during development testing of the refrigerator appliance at a number of different power supply conditions and preferably also at a number of different ambient temperatures which the appliance can be expected to see during its use. These various target defrost durations in association with the various mains voltages and ambient temperatures can be stored in a memory and can be used at the end of each defrost to calculate a new value for the subsequent refrigeration period. Also, fuzzy logic can be used. Alternatively, the target defrost duration can be calculated through a mathematical formula as a function of the detected power supply condition and preferably of the detected thermal dispersion. For example, a nominal target defrost duration of 30 minutes at 250 V mains voltage feeding the heater can be adjusted by an amount proportional to the square of the mains voltage deviation from the 250 V. For calculating target defrost durations a linear approximation can be sufficient. Preferably, the target defrost duration is calculated as a function of the thermal dispersion with a linear term and/or a quadratic term. A controller according to the present invention is preferably implemented using a microprocessor, and said look up table or said calculation routine of the target defrost duration can be stored in the microprocessor read-only memory or similar non volatile storage medium. The resulting programming complexity is well within the capabilities of a low-cost 4-bit or 8-bit microprocessor.

[0014] Preferably, the controller according to the present invention measures the refrigeration period in terms of compressor running time rather than in terms of total time between defrost operations. Reason for this is that the amount of ice accumulated on the evaporator can be regarded as approximately proportional to the accumulated running time of the compressor. It is, however, possible to use the total time, that is ON periods and OFF periods of the compressor during the refrigeration operation, for determining the refrigeration period.

[0015] In order to avoid that the duration of the defrost time interval varies at random due to different temperatures of the evaporator at the end of a refrigeration period, the controller according to the present invention preferably starts a defrost at a fixed evaporator temperature thus ensuring that the defrost operation is always timed between two fixed temperatures. The fixed evaporator temperature at which the defrost may be started by switching on the heater can vary according to the type of appliance. The fixed evaporator temperature at which a defrost is started is preferably programmed into the memory of the micro controller at the time of manufacture, for example by the use of an EEPROM or other non volatile programmable memory. It may be convenient for example to start a defrost after expiry of the refrigeration period time limit when the evaporator reaches a lower temperature threshold which is the thermostat cut-out point. This ensures that the defrost starts with a lower temperature in the food compartment thus avoiding excessive temperature rises in the food compartment during the defrost operation.

[0016] To cope in the manner indicated above with variations in the defrost time interval due to different temperatures of the evaporator at the end of the refrigeration period, it is not essential that means are provided for detecting a power supply condition and/or for determining the target defrost duration in accordance with the detected power supply condition.

[0017] Rather, this problem can also be solved using for instance a preset target defrost duration.

[0018] In order to allow a quick reaction to changes in the icing conditions for the evaporator, it is advantageous to reduce the refrigeration period, that is the time to the next defrost period, by an amount proportional to

the time the door is open during the refrigeration period between defrost periods, or proportional to the number of door openings during that period. Again, also this problem can be solved in the manner herein disclosed regardless whether a conventional preset target defrost duration is used or whether the target defrost duration is determined based on a detected thermal dispersion of the refrigerator.

[0019] The heater can take the form of a resistive heating element or can be the interior light within the food compartment. This will cause the evaporator temperature to rise to the desired preset defrost temperature at which point the defrost is terminated and normal temperature regulation is resumed.

[0020] In the following, preferred embodiments of the present invention will be described with reference to the accompanying drawings.

Fig. 1a shows time charts for illustrating the dependency of the duration of a defrost time interval on the condition of the power supply of the refrigerator;

Fig. 1b shows time charts for illustrating the dependency of the duration of a defrost time interval on the evaporator temperature at the end of a refrigeration period;

Fig. 2a shows an embodiment of a controller for controlling a defrost operation in a refrigerator in accordance with the present invention;

Fig. 2b shows a modification of the embodiment of Fig. 2a;

Fig. 3 shows a second embodiment of a controller for controlling a defrost operation according to the present invention;

Fig. 4a shows a third embodiment of a controller for controlling a defrost operation according to the present invention; and

Fig. 4b shows a time chart for illustrating the function of the controller according to the embodiment of Fig. 4a.

[0021] Fig. 2a shows a first embodiment of a controller for controlling a defrost operation in a refrigerator in accordance with the present invention. Reference numeral 1 in Fig. 2 denotes the controller. Reference numeral 2 denotes an evaporator connected via pipe means 3a and 3b to a compressor 3 for circulating cooling fluid through the evaporator 2 to achieve a cooling effect. Reference numeral 22 denotes a temperature sensor mounted in thermal contact with the evaporator 2. Reference numeral 4 denotes a refrigeration controller for performing normal temperature regulation inside a food compartment of the refrigerator. The refrigeration controller 4 receives an input from evaporator temperature sensor 22 and controls the operation of compressor 3. This refrigeration controller can be any kind of temperature controller, for instance a wellknown 2-point controller which keeps the evaporator temperature during a refrigeration period between a low temperature threshold and a high temperature threshold. Reference numeral 5 denotes a user-adjustable temperature dial for setting a desired temperature in the food compartment. Reference numeral 6 denotes a timer means for inhibiting normal temperature regulation of the refrigeration controller 4 after expiry of a refrigeration period time limit. The timer means 6 has a trigger input for triggering the timer. It furthermore has an input for setting a value for the refrigeration period time limit. After the timer has been triggered through its trigger input, it will output an inhibit signal to the refrigeration controller 4 after expiry of the set refrigeration period time limit. In this embodiment, during the refrigeration period the timer 6 counts the compressor running time and does not count time when the compressor is off. To this end the timer 6 receives from the refrigeration controller an indication on the operating state of the compressor.

[0022] Reference numeral 7 denotes a unit for measuring a defrost duration. Unit 7 receives an input from evaporator temperature sensor 22. It furthermore receives a preset defrost temperature value. It also receives an input from timer 6 indicating when a refrigeration period time limit has been reached and a defrost operation starts. Unit 7 for measuring a defrost duration begins a time measurement whenever this indication has been received from timer 6. Unit 7 terminates the measurement of the defrost time interval when the temperature measured by sensor 22 at the evaporator has reached the preset defrost temperature. Unit 7 outputs the actual defrost duration thus determined to a comparator 8a. Comparator 8a compares the actual defrost duration measured by unit 7 with a target defrost duration value and outputs a difference between the actual defrost duration and the target defrost duration to a unit 8b which calculates a new refrigeration period time limit based on the deviation of the actual defrost duration from the target defrost duration value. The calculated time limit in turn is input into timer 6 for setting the next refrigeration period time limit.

[0023] Reference numeral 13 denotes an electric heater arranged to supply heat to the evaporator when the same is defrosted. Heater 13 can be in thermal contact with the evaporator or can be arranged elsewhere within the food compartment. Heater 13 can be a resistive or inductive heating element or can be a light bulb for illuminating the food compartment. In this embodiment the heater 13 is switched on to receive electric power from the mains whenever timer 6 outputs an inhibit signal to refrigeration controller 4 to perform a defrost operation.

[0024] Reference numeral 19 denotes means for de-

tecting a voltage level of the mains supplying the refrigerator with power. The mains voltage level detected by unit 19 is input into a unit 10 for determining a target defrost duration value on the basis of the detected mains voltage. The target defrost duration thus determined is input into comparator 8a.

[0025] In this embodiment, the mains voltage detector 19 is a simple detector circuit consisting of a rectifier diode, a smoothing capacitor connected to that diode and a resistive voltage divider network for lowering the voltage across the capacitor down to a level that can be handled by an Analog to Digital converter circuit. Unit 10 for determining a target defrost duration receives the detected mains voltage level and converts it into a digital value. This digital mains voltage level value is then used by unit 10 to look up a table storing target defrost duration values for a variety of different mains voltage level values. Depending on whether the timer 6, the unit 7 for measuring a defrost duration, the comparator 8a and the unit 8b for calculating a refrigeration period time limit are implemented in digital or in analogue technology, the target defrost duration value looked up in the table of unit 10 is either input into comparator 8a for digitally determining a deviation between the actual defrost duration and the target defrost duration value, or unit 10 converts a value read from its look up table into an analogue value for further processing in comparator 8a.

[0026] Preferably, the controller 1 of this embodiment is implemented in digital technology by means of programming the functions of the timer 6, the unit 7 for measuring the defrost duration, the comparator 8a, the unit 8b for calculating a new refrigeration time limit and the unit 10 into a micro controller. The micro controller preferably has A/D conversion means on the chip for processing the analogue signals provided by temperature sensor 22 and the mains voltage level detector 19. Preferably, the micro controller furthermore implements the control functions of refrigeration controller 4.

[0027] As described above, unit 10 stores a table with different target defrost duration values associated with different mains voltage levels and preferably, moreover with different thermal dispersion values. It is noted that in the controller the determination of the target defrost duration in accordance with the detected power supply condition and possibly other parameters like detected thermal dispersion can be implemented in a variety of different ways. For example, the target defrost duration can be determined depending on these parameters without actually changing a target defrost duration value if the measured value indicating the duration of the defrost time interval is modified in accordance with these parameters before judging on the basis of the modified defrost time interval duration value whether an adjustment of the refrigeration period time limit is necessary. It is apparent that the existence of an explicit target defrost duration value and an explicit comparison of the defrost time interval duration with the target defrost duration is by no means mandatory for implementing a controller in accordance with the principles of the present invention.

[0028] To further illustrate one of the large varieties of different implementations of the same principle, Fig. 2b shows a modification of the embodiment of Fig. 2a. In Fig. 2b reference numeral 14 denotes a unit that receives from unit 7 a value indicative of the measured defrost time interval duration. Unit 14 furthermore receives from detector 19 a value indicative of the power supply condition of the refrigerator, e.g. the mains voltage level. Unit 14 modifies the received defrost time interval duration value in accordance with the received power supply condition value and outputs the modified duration value to unit 8b that calculates the next refrigeration period time limit based on the modified duration value received from unit 14. Unit 8b can be implemented in the form of a table that associates refrigeration period time limits to a variety of received duration values. Instead of using tables unit 8b can of course evaluate an analytical function that relates refrigeration period time limits to modified defrost duration values received from unit 14.

[0029] Unit 14 can be implemented to operate such that it calculates a duration value $t_{rated}=t_{real}(U^2_{real}/U^2_{rated})$. The entity t_{real} denotes the measured defrost duration. The entity t_{rated} is a modified defrost duration value that takes into account the variation of the thermal energy supplied by the heater during the defrost time interval as a function of a ratio between the rated mains voltage and the real mains voltage detected by unit 19. In order to take into account that even if the thermal energy supplied by heater 13 is zero the evaporator 2 will eventually reach the preset defrost temperature under normal environmental conditions, and that even if the thermal energy supplied by the heater were very large the defrost time interval duration would not be zero, a correction factor k can be provided in accordance with the following formula:

$$t_{cor}=t_{real}+k\ (t_{rated}-t_{real}).$$

[0030] In this formula, t_{cor} denotes a corrected defrost time interval duration value. The value k is empirically determined to be between 0 and 1. For k=1, the value t_{cor} is identical with t_{rated}. For k=0 there will be no modification of the measured defrost time interval duration in accordance with the detected mains voltage. The value t_{cor} is output to unit 8b for calculating the next refrigeration period time limit.

[0031] The mains voltage U_{real} can be obtained for instance by means of sampling and preferably averaging the samples obtained during the defrost period.

[0032] Fig. 3 shows a second embodiment of a controller for controlling a defrost operation of a refrigerator in accordance with the present invention.

[0033] All elements in Fig. 3 identical with or corresponding to elements in Fig. 2a have been denoted with

the same reference numerals. The description of these elements given with regard to Fig. 2a or Fig. 2b similarly applies to the embodiment of Fig. 3, unless stated otherwise in the following.

[0034] The embodiment of Fig. 3 differs from the embodiment of Fig. 2a in the provision of an ambient temperature detection means 9. According to the second embodiment of Fig. 3, the ambient temperature detection means 9 receives a signal from temperature sensor 22 on the evaporator 2. It furthermore receives a signal from refrigeration controller 4 indicating the operating state of the compressor, that is whether the compressor is currently in the ON state or in the OFF state. The embodiment of Fig. 3 is advantageous in that the ambient temperature detection means 9 does not require a separate temperature sensor for sensing the ambient temperature. Rather, the ambient temperature detection means 9 estimates thermal dispersion of the refrigerator based on the temperature curve of the evaporator temperature 22. Preferably, the ambient temperature detection means 9 calculates a rate of rise of evaporator temperature when the compressor is off. It furthermore calculates a rate of fall of evaporator temperature when the compressor is on. It then calculates the ratio of said rate of rise to said rate of fall. This ratio indicates the thermal dispersion of the refrigerator largely independent of food load variations in the food compartment of the refrigerator.

[0035] These rates of rise or fall can be measured either over a constant time period or over a constant temperature change. A simple way to determine the rate of change over a constant temperature is to measure the time t_{off} that the compressor is off and the time t_{on} that the compressor is on, during normal temperature regulation of the refrigeration controller 4, that is in the course of a refrigeration period. The ratio t_{on}/t_{off} is essentially equivalent to the ratio of the rate of rise of evaporator temperature when the compressor is off to the rate of fall of evaporator temperature when the compressor is on, as long as the low temperature threshold and the high temperature threshold used by the refrigeration controller 4 controlling the compressor 3, remain unchanged. Thus, if the ambient temperature detection means 9 is adapted to evaluate the thermal dispersion of the refrigerator from the ratio of t_{on}/t_{off}, then the ambient temperature detection means 9 need not receive a signal from temperature sensor 22.

[0036] The thermal dispersion ratio is preferably calculated by unit 9 on a continuous basis in the course of every refrigeration period. Each time the compressor changes its operating state from ON to OFF or from OFF to ON, unit 9 provides a new value for the thermal dispersion ratio to unit 10. In this embodiment, unit 10 has a look up storing target defrost duration values for a variety of different mains voltage level values and for a variety of different thermal dispersion values. In order to avoid an adverse influence of disturbing factors like frequent or long door openings or the introduction of extremely or cold goods into the food compartment onto the evaluation of the thermal dispersion it is advantageous to provide the thermal dispersion detection means 9 with means for detecting whether said calculated thermal dispersion ratio is stable or not. To this end, unit 9 can be provided with memory locations for storing a predetermined number of preceding thermal dispersion ratios, and with means for investigating whether the stored thermal dispersion ratios differ from each other by more than a predetermined threshold variance. Each time a new thermal dispersion ratio is calculated by unit 9, the oldest thermal dispersion ratio in said memory locations is replaced by the newest. If the differences between the stored thermal dispersion ratios is smaller than said predetermined variance threshold, the detected thermal dispersion ratio will then be used by unit 10 for calculating an updated target defrost duration value on the basis of the detected ambient conditions. Otherwise, unit 10 will maintain unchanged the target defrost duration value output to unit 8a unchanged until the conditions for detecting a thermal dispersion ratio have been stabilized, that is, until all thermal dispersion ratios stored in unit 9 differ from each other by no more than said predetermined variance threshold.

[0037] Unit 8b for determining an updated refrigeration period time limit based on a deviation of the actual defrost duration from the target defrost duration given by unit 10 can be provided to increase the refrigeration period time limit each time the actual defrost duration is smaller than the target defrost duration, and to decrease the refrigeration period time limit each time the actual defrost duration has been found to be larger than the target defrost duration. In the alternative, unit 8b may contain a look up table storing a plurality of refrigeration period time limits in association with respective defrost duration deviation values.

[0038] Unit 7 for measuring the actual defrost duration comprises a time counter the operation of which is started when receiving an end of refrigeration period signal from timer 6. The time counter stops counting when a comparator for comparing the actual evaporator temperature from temperature sensor 22 with a preset defrost temperature value indicates that the evaporator temperature 22 has reached the preset defrost temperature. At this stage unit 7 outputs the end of defrost signal to trigger timer 6 for starting a new refrigeration period. Unit 7 then furthermore outputs the actual defrost duration value to comparator 8a.

[0039] The embodiment of Fig. 3 can be modified in a way similar to the modifications shown and described in Fig. 2b. In this modification unit 14 modifies the measured defrost duration in accordance with the detected mains voltage level and in accordance with the detected thermal dispersion of the refrigerator.

[0040] Fig. 4a shows a third embodiment of a controller according to the present invention. This embodiment differs from the embodiment shown in Fig. 2a in the pro-

vision of a unit 11 for updating the refrigeration period time limit set in timer 6. Unit 11 for updating the time limit of timer 6 receives an input from a door position sensor 12. All remaining elements of Fig. 4a are identical with the corresponding elements of Fig. 2a and are denoted with the same reference numerals, such that their description need not be repeated.

[0041] The embodiment of Fig. 4a addresses the problem that the refrigeration period time limit calculated in unit 8b and set in timer 6 has been determined on the basis of the duration of the preceding defrost operation. If in the course of the refrigeration period there are frequent or long lasting door openings, the time limit for the refrigeration period calculated by unit 8b is no longer up to date.

[0042] Unit 11 for updating the refrigeration period time limit counts the total time for which the door of the food compartment of the refrigerator is open during the refrigeration period. The total time count is received by timer 6, and the timer 6 subtracts the current total time count from the current period of time left until the refrigeration period time limit is reached. As soon as the updated refrigeration period time limit has been reached, the defrost period starts and the timer means 6 outputs a signal to unit 11 to reset the open door time counter. By means of providing unit 11 for updating the refrigeration period time limit, the controller according to this embodiment is able to reduce the refrigeration period based on an estimation of additional ice accumulation due to door openings without waiting for the next measurement of a defrost duration. A controller according to this embodiment can, therefore, quickly cope with changes in the actual icing conditions of the evaporator and keep the defrost operation of the refrigerator energy-efficient.

[0043] In the alternative to measuring the total door open time period during a refrigeration period, unit 11 can be provided to count the number of door openings during the refrigeration period. This alternative is, however, inferior to counting the total door open time period in that it will not be able to appropriately react to the situation that the door of the food compartment is opened and left open.

[0044] While the embodiment of Fig. 4a includes a unit 10 for calculating a target defrost duration and a unit 19 for detecting a mains voltage level of the refrigerator, the units 9 and 10 are not essential for solving the problem to enable a controller for controlling a defrost operation of a refrigerator to quickly react to changes of the icing conditions of the evaporator due to frequent or long lasting door openings.

[0045] Fig. 4b is a time chart illustrating the behavior of the evaporator temperature and the sequence of refrigeration periods and defrost periods according to the third embodiment shown in Fig. 4a. The time chart of Fig. 4b shows a refrigeration period n and the evaporator temperature T in the course of that refrigeration period n. No door openings take place during that period n. At the end of the refrigeration period n, an n^{th} defrost operation takes place. The measured duration of the n^{th} defrost period influences the duration of the subsequent refrigeration period (n+1). During that refrigeration period n+1, door openings take place, as indicated in the bottom part of Fig. 4b. The duration of these door openings is counted by unit 11 for updating the refrigeration period time limit, and the actual count is subtracted from the time count in timer 6 which indicates the remaining time of the refrigeration period n+1. This has the effect shown in Fig. 4b that the total refrigeration period n+1 with door openings having taken place is shorter than the refrigeration period n. Updating the refrigeration period time limit on the basis of door openings furthermore has the effect that also the $(n+1)^{st}$ defrost duration is not significantly different from the n^{th} defrost duration since the increased accumulation of ice on the evaporator due to the door of the refrigerator having been open is compensated by means of advancing the next defrost operation, such that both in refrigeration period n and in refrigeration period n+1 the peak amount of ice accumulated on the evaporator is substantially the same.

[0046] The embodiment of Fig. 4a can be modified in a variety of different ways. The modifications described in connection with Fig. 2b are of course applicable also to the embodiment of Fig. 4a.

Claims

1. A controller (1) for controlling a defrost operation in a refrigerator having at least one food compartment, at least one evaporator (2) for cooling said food compartment, electrical heater means for supplying heat to defrost said evaporator, and a compressor (3) for circulating cooling fluid through said evaporator, the controller (1) comprising

    - means (4) for controlling a refrigeration operation of said compressor (3);
    - timer means (6) for defrosting said evaporator after expiry of a refrigeration period time limit;
    - means (7) for measuring a duration of a defrost time interval ending with said evaporator (2) having reached a preset defrost temperature;
    - means (8a, 8b) for comparing said defrost time interval duration with a target defrost duration and setting said refrigeration period time limit in accordance with a deviation of said defrost time interval from said target defrost duration;

    characterized by

    - means (9) for detecting a power supply condition for said heater means; and

- means (10, 14) for determining said target defrost duration in accordance with said detected power supply condition.

2. The controller according to claim 1, characterized in that said means for detecting a power supply condition of said electrical heater means is adapted to detect a voltage of the mains to which the refrigerator is connected, or to detect a supply current through said heater means.

3. The controller according to claim 1 or 2, characterized by means for energizing said heater means when defrosting said evaporator.

4. The controller according to any one of the preceding claims,
characterized by

- means (9) for detecting a thermal dispersion of said refrigerator.

5. The controller according to claim 4,
characterized in that

- said means (9) for detecting a thermal dispersion comprises a temperature sensor for detecting an ambient temperature and /or is adapted to estimate an ambient temperature of the refrigerator on the basis of a rate of rise of evaporator temperature when the compressor (3) is off and/or on the basis of a rate of fall of evaporator temperature when said compressor (3) is on.

6. The controller according to claim 5,
characterized in that

- said means (9) for detecting a thermal dispersion is adapted to estimate the ambient temperature of said refrigerator on the basis of a thermal dispersion ratio of said rate of rise of evaporator temperature when said compressor (3) is off to said rate of rise of evaporator temperature when said compressor (3) is on.

7. The controller according to claim 6,
characterized in that

- said means (9) for detecting a thermal dispersion is adapted to measure an OFF time period and an ON time period of the compressor (3) during said refrigeration period and to evaluate said thermal dispersion ratio based on a ratio of said compressor ON time period to said compressor OFF time period or based on a ratio of said compressor ON time period to a sum of said compressor ON time period and said compressor OFF time period.

8. The controller according to any one of the preceding claims,
characterized in that

- said means (10) for determining a target defrost duration comprise memory means for storing a look up table which comprises a plurality of power supply conditions and associated target defrost duration values.

9. The controller according to any one of the preceding claims,
characterized in that

- said means (8a, 8b) for comparing said defrost time interval with a target defrost duration and setting said refrigeration period time limit in accordance with a deviation of said defrost time interval from said target defrost duration includes memory means for storing a look up table comprising a plurality of target defrost duration values, defrost time interval values and associated refrigeration period time limit values.

10. The controller according to any one of the claims 1 to 8,
characterized in that

- said means (8a, 8b) for comparing said defrost time interval with a target defrost duration and setting said refrigeration period time limit in accordance with a deviation of said defrost time interval from said target defrost duration is adapted to increment said refrigeration period time limit if said defrost time interval is smaller than said target defrost duration, and to decrement said refrigeration period time limit if said defrost time interval is larger than said target defrost duration.

11. The controller according to any one of the claims 1 to 7, characterized in that

- said means for determining the target defrost duration comprises means (14) for modifying a value indicative of the measured defrost time interval duration in accordance with said power supply condition detected by said detection means (9); and

- said means (8b) for comparing said defrost time interval duration with a target defrost duration is adapted to set said refrigeration period time limit in accordance with said modified value indicative of the measured defrost time interval

duration received from said modified means (14).

12. The controller according to any one of the preceding claims,
characterized by

- means (12) for detecting whether a door of said food compartment is open, and for accumulating an open door time period during each refrigeration period;
and

- means (11) for reducing said refrigeration period time limit in accordance with said accumulated open door time period.

13. The controller according to claim 12,
characterized in that

- said means (11) for reducing said refrigeration period time limit is adapted to reduce said refrigeration period time limit in proportion to said accumulated open door time period or in proportion to a counted number of door openings.

14. The controller according to any one of the preceding claims,
characterized in that

- said defrost time interval measuring means (7) is adapted to start measuring said defrost time interval with the expiry of said refrigeration period time limit.

15. The controller according to any one of the claims 1 to 13,
characterized in that

- said timer means (6) for inhibiting an operation of said compressor (3) after expiry of a refrigeration period time limit and defrosting said evaporator is adapted to receive a signal indicating an actual temperature of said evaporator (2); and

- to inhibit the operation of said compressor (3) and start defrosting said evaporator (2) when said refrigeration period time limit has expired and said evaporator temperature has reached below a predetermined defrost start temperature;

- said defrost time interval measuring means (7) being adapted to start measuring said defrost time interval when said evaporator temperature has reached said defrost start temperature.

16. The controller according to claim 15,
characterized in that

- said timer means (6) is adapted to initiate an additional compressor ON phase when said refrigeration period time interval expires and said evaporator temperature is above said preset defrost start temperature, and to end said additional compressor ON phase when said evaporator (2) has reached said defrost start temperature.

17. The controller according to claim 15 or 16,
characterized in that

- said means (4) for controlling a refrigeration operation is adapted to activate said compressor (3) when the evaporator temperature has reached an upper temperature threshold, and to switch off said compressor (3) when the evaporator temperature has reached a lower temperature threshold;

- said defrost start temperature being said lower temperature threshold.

18. The controller according to any one of the preceding claims,
characterized by

- said means for energizing said heating means is adapted to energize said heating means when said refrigeration time limit has expired and said evaporator temperature has reached below said predetermined defrost start temperature, and to deenergize said heating means when said evaporator temperature has reached said preset defrost temperature.

19. The controller according to any one of the claims 2 to 18,
characterized by

- said means for energizing said heating means being connected to energize a door operated for said food compartment.

20. The controller according to any one of the preceding claims,
characterized in that

- said timer means (6) is adapted to measure said refrigeration period by means of accumulating compressor running time only, or by means of measuring real time.

21. The controller according to any one of the preceding claims,

characterized in that

- said means (4) for controlling a refrigeration operation of said compressor (3) is adapted for controlling in accordance with a user settable food compartment target temperature value (5).

22. A method of controlling a defrost operation in a refrigerator having a food compartment, an evaporator (2) for cooling said food compartment, electrical heater means for supplying heat to defrost said evaporator, and a compressor (3) for circulating cooling fluid through said evaporator, the method comprising the steps of

- controlling a refrigeration operation of said compressor (3)
- defrosting said evaporator (2) after expiry of a refrigeration period time limit by means of energizing said heater means, and
- measuring a defrost time interval ending with said evaporator (2) having reached a preset defrost temperature;
- comparing said defrost time interval with a target defrost duration and setting said refrigeration period time limit in accordance with a deviation of said defrost time interval from said target defrost duration;

characterized by

- detecting a power supply condition for said heater means; and
- determining said target defrost duration in accordance with said detected power supply condition

23. The method according to claim 22, characterized by said detected power supply condition being a voltage of the mains to which the refrigerator is connected or a supply current through said heater means.

24. A refrigerator having at least one food compartment, at least one evaporator (2) for cooling said food compartment, electrical heater means for supplying to defrost said evaporator, and a compressor (3) for circulating cool fluid through said evaporator, comprising a controller according to any one of the claims 1 to 22.

FIG.1a

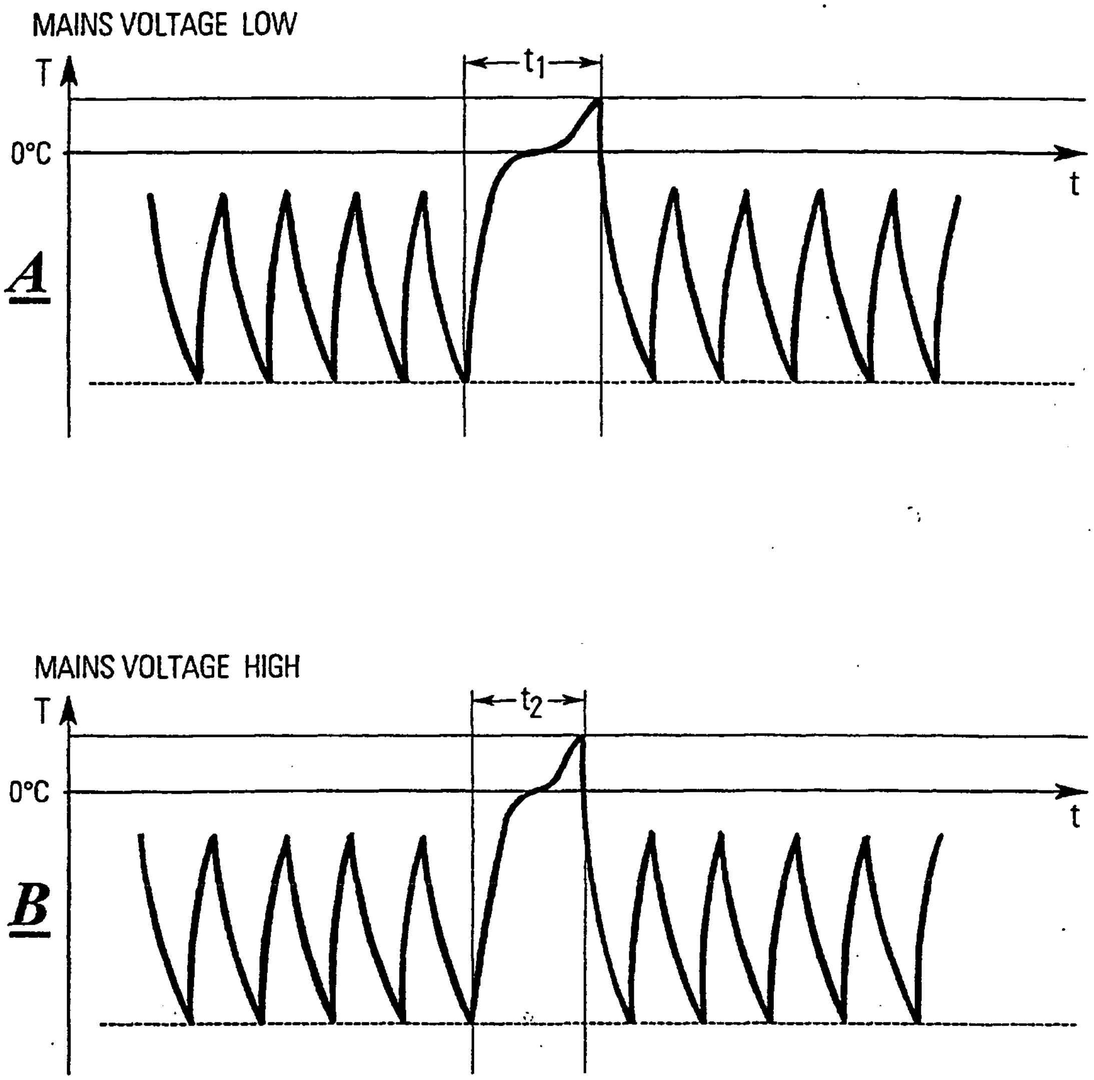


FIG.1b

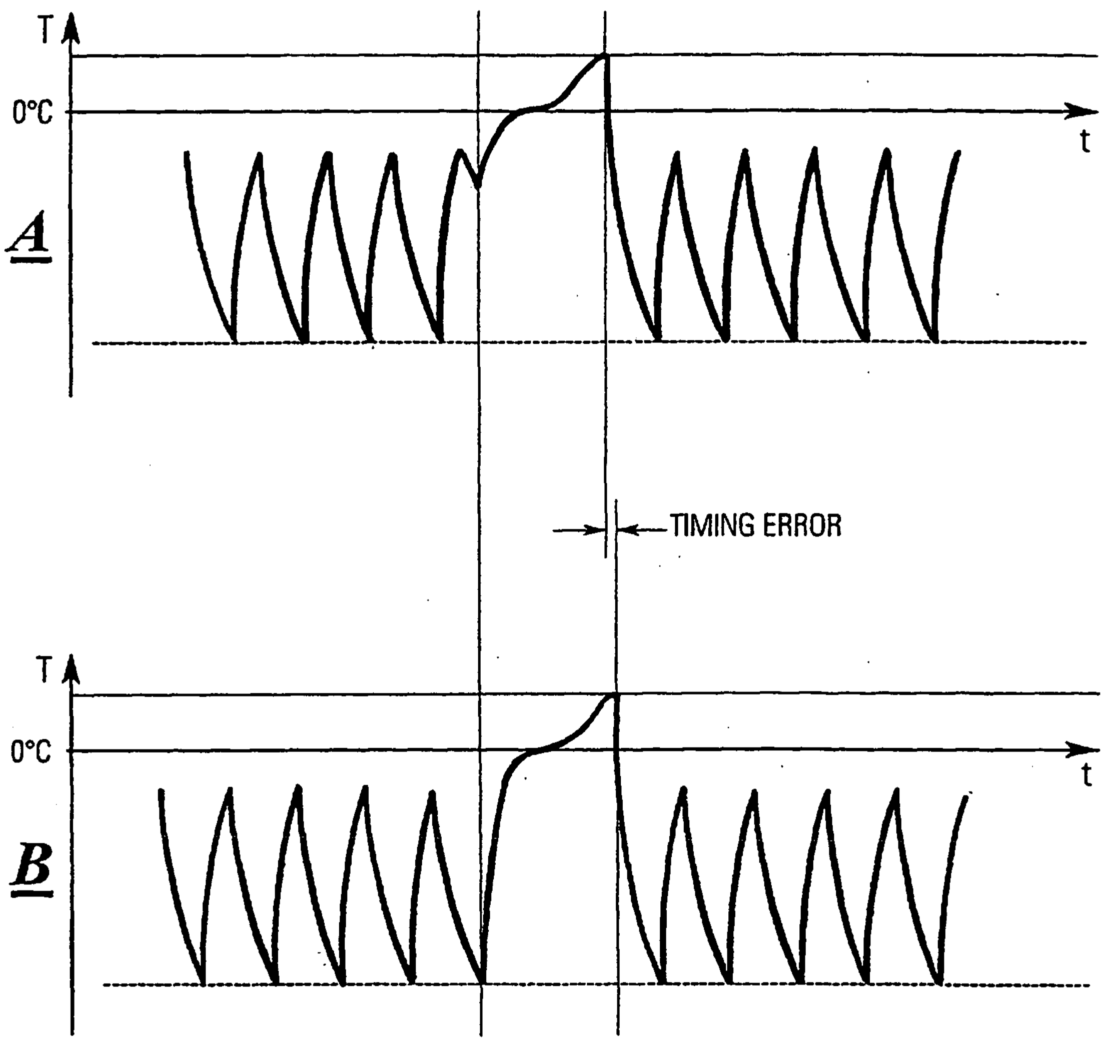


FIG.2a

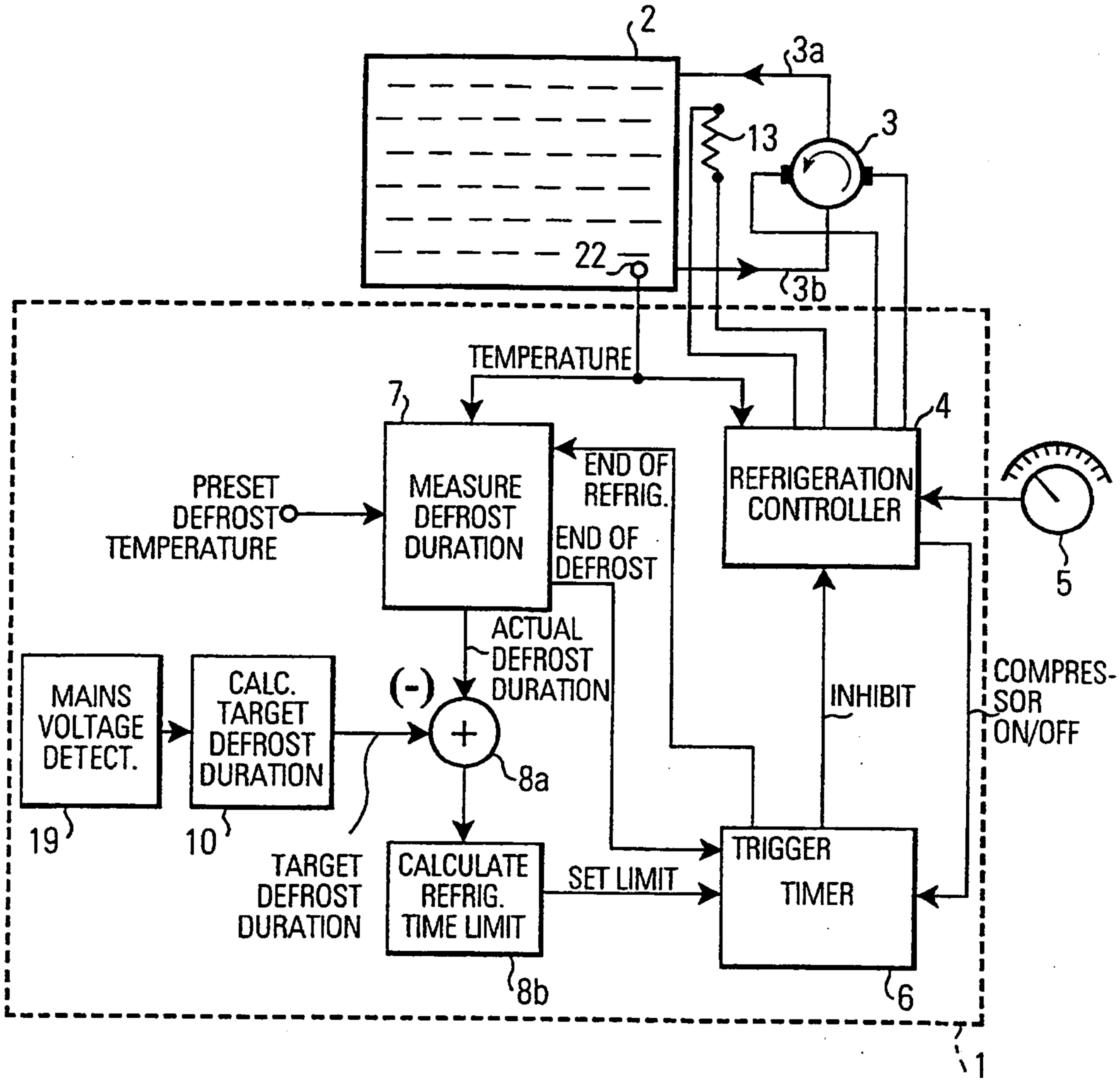

2
3a
13
3
22
3b
TEMPERATURE
7
4
PRESET
DEFROST
TEMPERATURE
MEASURE
DEFROST
DURATION
END OF
REFRIG.
END OF
DEFROST
REFRIGERATION
CONTROLLER
5
ACTUAL
DEFROST
DURATION
MAINS
VOLTAGE
DETECT.
CALC.
TARGET
DEFROST
DURATION
(-)
+
8a
INHIBIT
COMPRES-
SOR
ON/OFF
19
10
TARGET
DEFROST
DURATION
CALCULATE
REFRIG.
TIME LIMIT
SET LIMIT
TRIGGER
TIMER
8b
6
1

FIG.2b

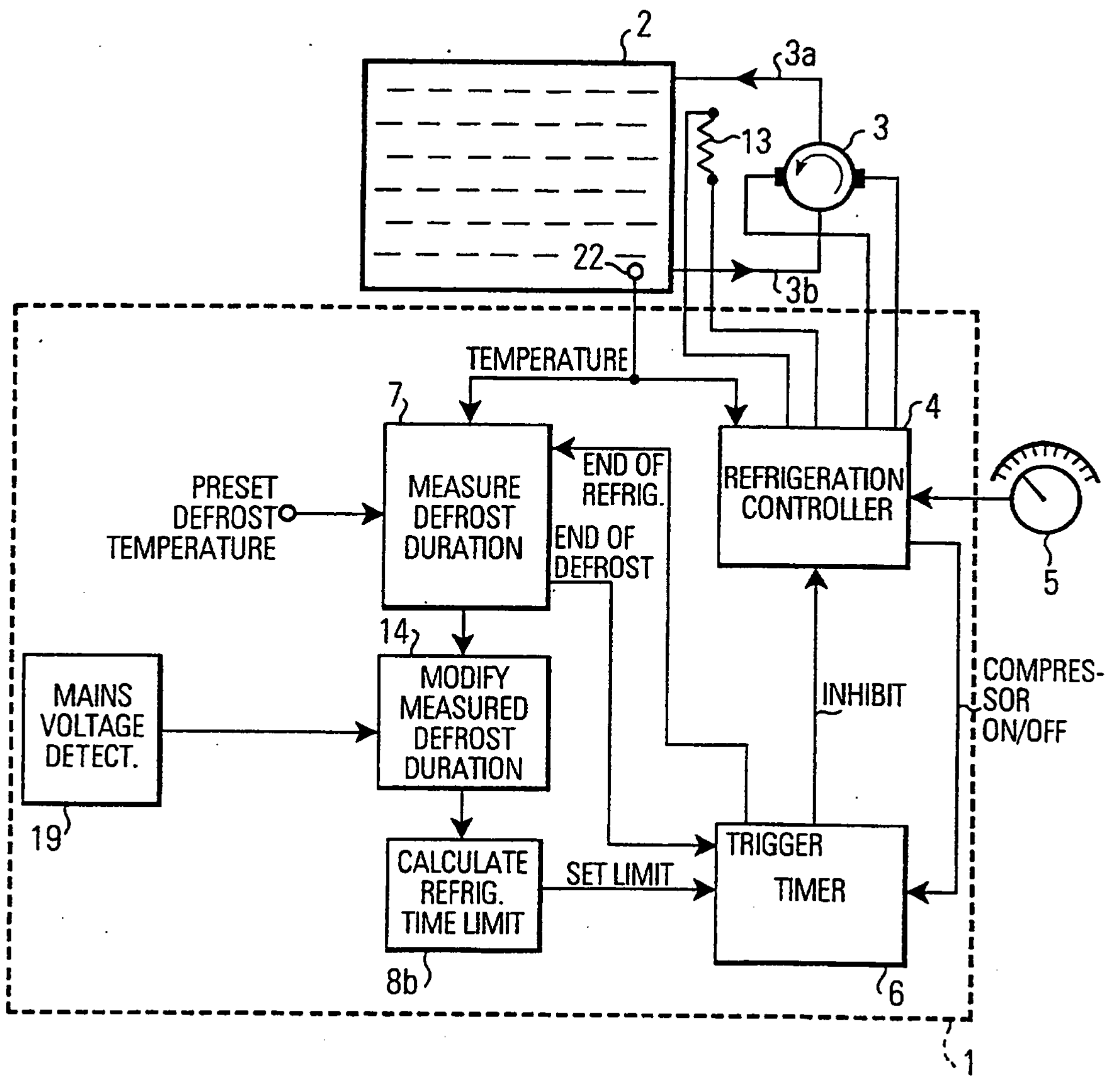

2
3a
13
3
22
3b
TEMPERATURE
7
4
MEASURE DEFROST DURATION
PRESET DEFROST TEMPERATURE
END OF REFRIG.
END OF DEFROST
REFRIGERATION CONTROLLER
5
14
MAINS VOLTAGE DETECT.
MODIFY MEASURED DEFROST DURATION
INHIBIT
COMPRES-SOR ON/OFF
19
CALCULATE REFRIG. TIME LIMIT
SET LIMIT
TRIGGER
TIMER
8b
6
1

FIG.3

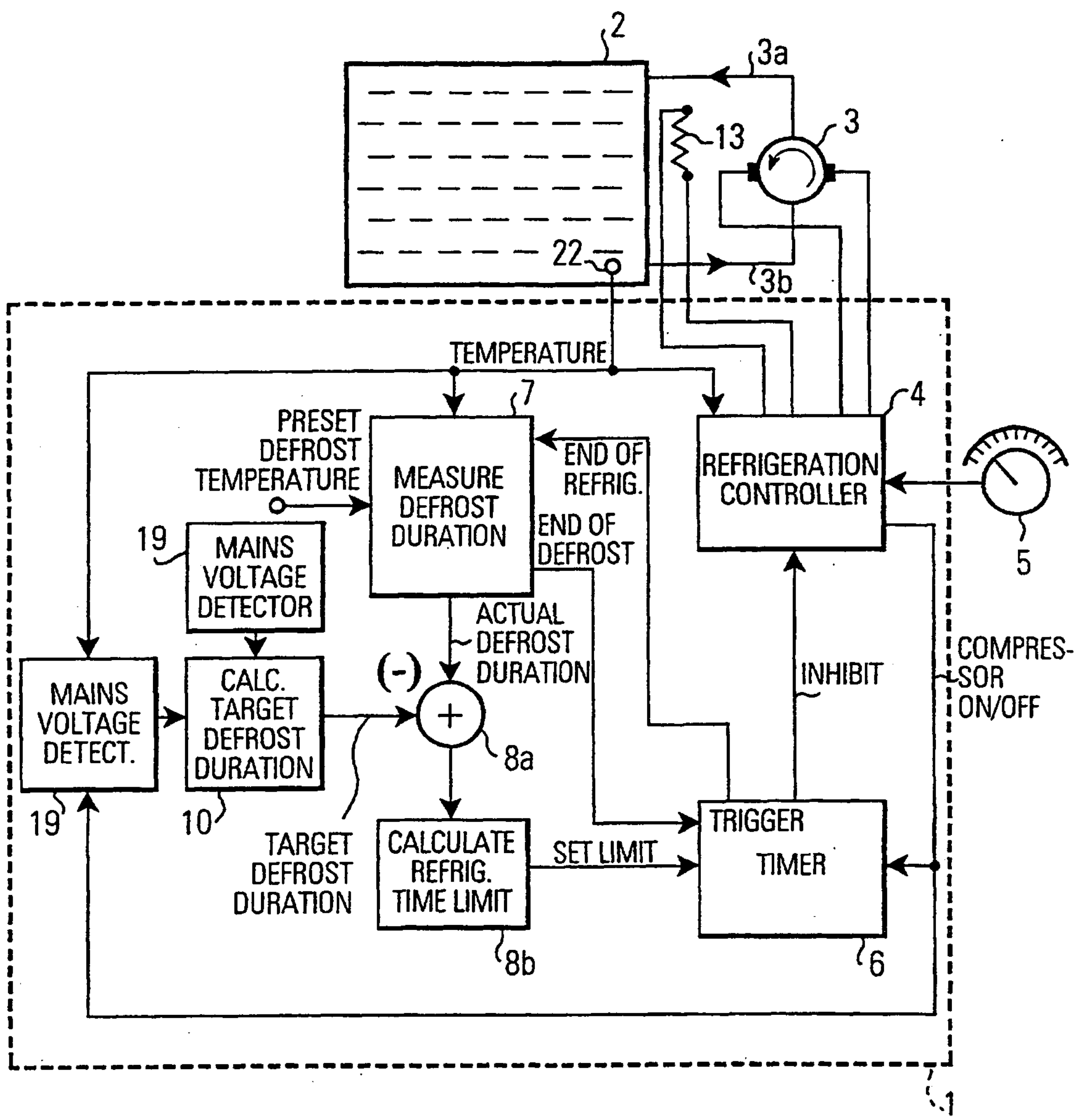

2
3a
13
3
22
3b
TEMPERATURE
7
4
PRESET
DEFROST
TEMPERATURE
MEASURE
DEFROST
DURATION
END OF
REFRIG.
END OF
DEFROST
REFRIGERATION
CONTROLLER
5
19
MAINS
VOLTAGE
DETECTOR
ACTUAL
DEFROST
DURATION
INHIBIT
COMPRES-
SOR
ON/OFF
MAINS
VOLTAGE
DETECT.
CALC.
TARGET
DEFROST
DURATION
(-)
+
8a
19
10
TARGET
DEFROST
DURATION
CALCULATE
REFRIG.
TIME LIMIT
SET LIMIT
TRIGGER
TIMER
8b
6
1

FIG.4a

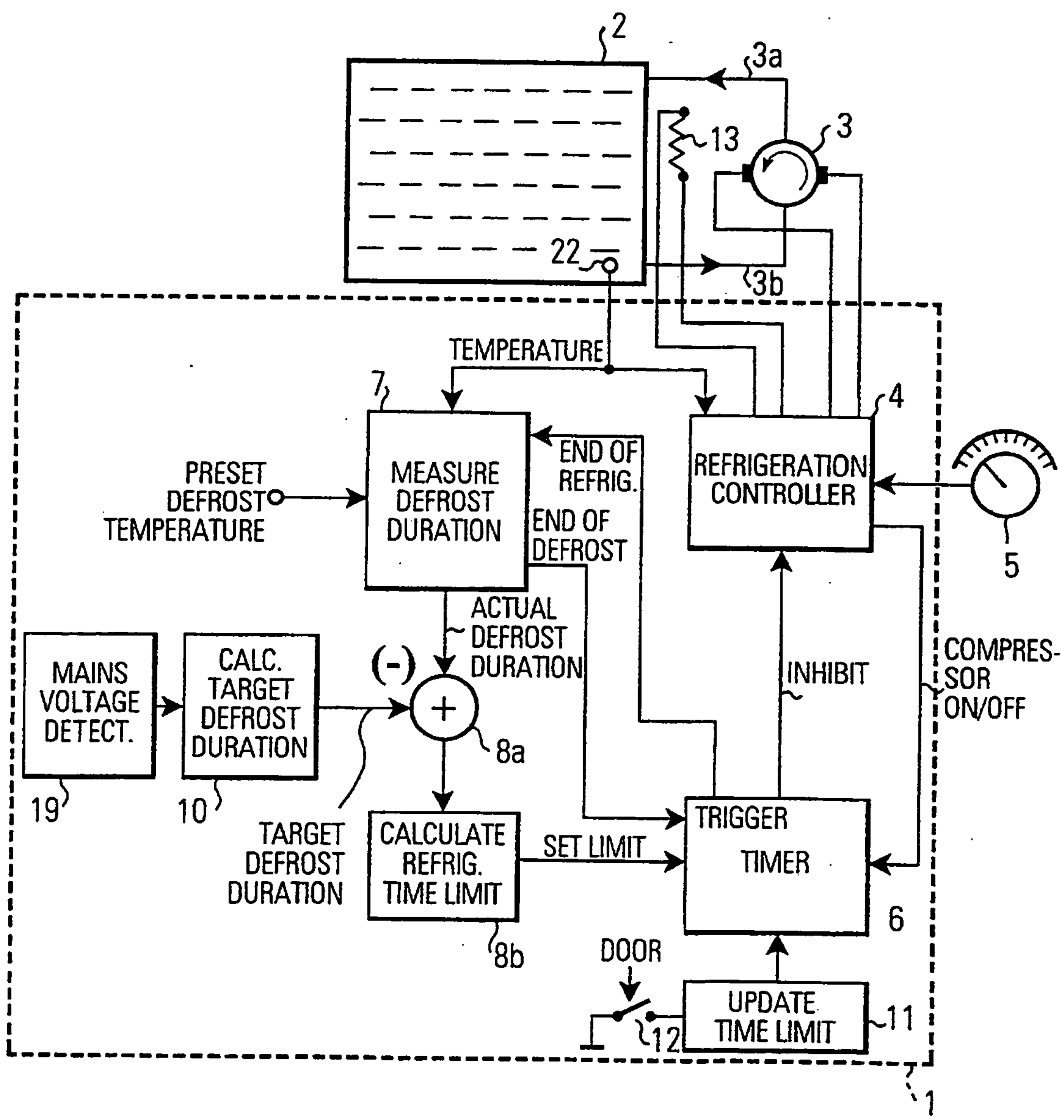
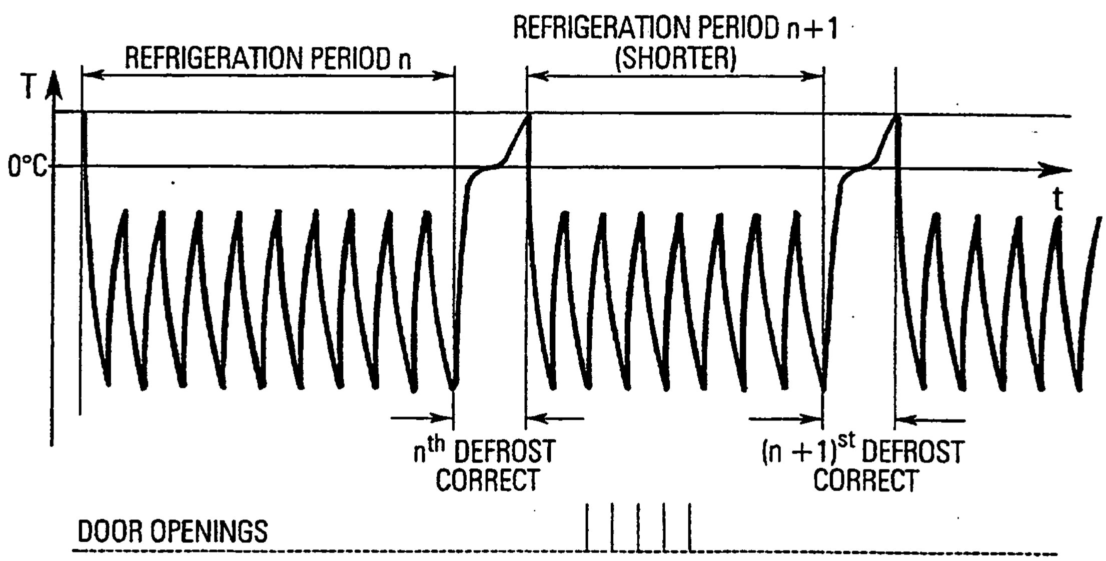

2
3a
13
3
22
3b
TEMPERATURE
7
4
MEASURE DEFROST DURATION
END OF REFRIG.
REFRIGERATION CONTROLLER
PRESET DEFROST TEMPERATURE
END OF DEFROST
5
ACTUAL DEFROST DURATION
COMPRES-SOR ON/OFF
MAINS VOLTAGE DETECT.
CALC. TARGET DEFROST DURATION
(-)
+
INHIBIT
8a
19
10
TARGET DEFROST DURATION
CALCULATE REFRIG. TIME LIMIT
SET LIMIT
TRIGGER
TIMER
6
8b
DOOR
UPDATE TIME LIMIT
11
12
1

FIG.4b


REFRIGERATION PERIOD n
REFRIGERATION PERIOD n+1
(SHORTER)
T
0°C
t
n^th DEFROST
CORRECT
(n +1)^st DEFROST
CORRECT
DOOR OPENINGS

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 00 11 7310

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	31 January 2001	Boets, A

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European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 00 11 7310

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	31 January 2001	Boets, A

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